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TERRAIN NAVIGATION TRAINING FOR HELICOPTER PILOTS USING A VIRTUAL ENVIRONMENT

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INTRODUCTION

To date, virtual environments applied to aviation training have been created under the assumption that flying is flying and that tools to train pilots are basically independent of the type of aircraft in question. This is in fact not the case at all. Most of the training tools that have been developed over the years for the fixed wing community are fundamentally inappropriate for the rotary wing community. Systems such as TOPSCENE [1], which has been widely regarded as an excellent mission rehearsal system for fixed wing pilots, is seldom even used by rotary wing pilots because it does not represent the information helicopter pilots need in the form that they will see it. High and fast is different from low and slow. These differences must be accounted for in training systems for helicopter pilots by providing tools *specifically* designed for their needs and missions.

Navigation is an essential component of all helicopter missions. While most training time is spent on mission-specific items and procedures, all goes for naught if the pilot cannot find the target. Surprisingly, navigation does not receive much attention at all in the training curriculum. At Helicopter Antisubmarine Squadron Ten (HS-10), the SH-60F and HH-60H Fleet Replacement Squadron (FRS), three days of the 160 day curriculum are spent on Combat Search and Rescue (CSAR) ground school, a part of which is MITAC (Map Interpretation and Terrain Association Course). Of course, with such little emphasis spent on map reading and navigation, pilots tend to struggle with the two flights they must make to demonstrate mastery of these skills. A lot of time is spent in the air circling checkpoints, recovering from errors, and generally showing student pilots that flying over Southern California is very different from flying over Pensacola, Florida, where they conduct initial terrain navigation training.

Background

Historically, CSAR ground school was a two week long school and MITAC training received much greater emphasis. However, even then, training techniques were less than optimal, and in some cases, counterproductive. Many of the pilots in the fleet today received MITAC training from a videotape filmed from a Huey UH-1 and played back at about double speed. The task was to watch the video and chart progress with a grease pencil on a laminated contour map. This type of training has a number of shortcomings. With the limited field of view available on a videotape, pilots do not learn how to use peripheral vision to maintain orientation. At accelerated speeds, pilots learn that the only way to maintain position on the map is to pick out landmarks (peaks or other terrain features) at great distances. This causes them to stop paying attention to what is right in front of the aircraft. There is also a complete lack of interaction in the video. If a mistake is made, there is no way for the student to go back and determine what caused it. This is a fundamental part of learning.

What has resulted is a situation where navigation skills today are almost entirely learned in the aircraft. Considering the maintenance costs of a typical military helicopter, this is an expensive way to learn. Even if it wasn't so expensive, there is another problem. Flight instructors at HS-10 are restricted as to what routes they can fly. They are not free to make up new routes at will. Consequently, once a student pilot has flown a route, all map and terrain interpretation stops. It then becomes a memory or landmark recognition task of "How did I do this last time?" rather than map reading. The ability to fly unique routes would greatly enhance the flight instructor's ability to teach this skill. Even if alternate routes were available, flight instructors would not be able to evaluate student's navigation ability over terrain types other than Southern California and Arizona. How well can they navigate over the desert? How well can they navigate over relatively featureless terrain? Navigation training in the air is not only excessively expensive, but also limited in effectiveness.

Helicopters are flown by two pilots -- one maintains control of the aircraft and is responsible for avoiding hazards (e.g. power lines and vegetation) and for verbally identifying features for the navigator who is responsible for charting the current position and for guiding the flying pilot. This is typically done with verbal commands. The important factor here is that the navigating pilot is not doing the flying. These pilots already know how to fly. Our objective is not to teach flying but to teach navigation skills. Therefore, if a single pilot is to learn how to navigate, the interface to the training system must have no learning curve associated with it. It should be as near to "walk up and use" as possible.

Requirements

In summary, what HS-10 needs is a way to allow student pilots to fly unique routes over real (or topologically similar) terrain while reading a contour map. They must be able to review their flights to get appropriate feedback as to where mistakes were made. They should not be left in a disoriented condition for prolonged periods of time. This causes frustration, diminished self confidence, and is otherwise not helpful to the training process. Ideally, much of this can and should be done outside of instructor view. Students who are not adept at navigation skills know it. If they had a way to develop and hone their skills before a graded flight, they would certainly do so. However, no such mechanism currently exists other than extra map study. The interface to this system must be simple to use. It doesn't need to be like real flying since the navigator doesn't do the flying anyway. This training capability must be made available at the squadron level. If an expensive large-scale solution were to be developed, it would not be used due to a lack of availability by individual pilots on an as-needed basis.

APPROACH

There are a number of practical constraints, in addition to those defined by the needs of HS-10, to constructing, evaluating, and eventually fielding a trainer of this type. Since the system must be available on an as-needed basis at the squadron level, it must therefore be relatively inexpensive and easy to maintain. HS-10 does not have the manpower nor the financial resources to accommodate another large expensive training system in addition to the full motion flight simulators they already maintain. We envisioned a small system that could occupy a corner in a classroom or ready room. This would allow for asynchronous training to occur – the student can use the system without instructor intervention.

Ideally, the system would be implemented on general purpose hardware. This would make it easier to maintain and develop further. The current implementation almost achieves this goal. It is small and transportable but uses specialized graphics hardware. We felt that this was a reasonable compromise at this time since PC graphics hardware is improving at such a rapid pace. We believe that in the time it takes us to determine what the system has to look like and we evaluate that it is effective, the time will be right to port the system to a graphics PC. This work is in its early stages at this time.

After determining what the general training need was at HS-10, we developed a rough implementation and brought it to HS-10 for their feedback. We learned that they specifically did not want a mission rehearsal system like TOPSCENE but rather needed something to help students learn to read contour maps. As we worked on the second iteration, we used students at the Naval Postgraduate School and specifically the Aviation Safety School in several usability tests to work out the details of the interface. At this point, the system was brought to HS-10 to begin data collection on the actual training effectiveness experiment.

IMPLEMENTATION

The prototype navigation trainer was implemented on an Indigo2™ graphics workstation from Silicon Graphics, Inc. (SGI). The system contains a single R4400 200 MHz CPU with 128 Mbytes of RAM, a High Impact™ graphics board, and IMPACT™ Channel Option Board to allow the use of multiple graphics monitors from a single machine. The display setup uses three 19" monitors in a semicircular configuration. The three monitors provide about 95° field of view when sitting 27" from the screens. The control device is a Flybox™ from BG Systems, Inc. Figure 1 shows the basic configuration of the system. The fourth monitor shown is used as a console and is not used as a display during training.

Figure 1. The apparatus for the prototype helicopter navigation trainer.

Software

The software was developed entirely at the Naval Postgraduate School using the Performer™ application programmers interface (API) from SGI. At its heart is a simple terrain fly through program augmented with the necessary maps and gauges required for this application. The flight control was designed to be as simple as possible. We use a terrain following technique such that the pilot sets a course (bearing), altitude above ground level (AGL), and ground speed in knots. There is a minimum altitude of 50' AGL so that crashing into the ground is impossible. There is no maximum altitude. The pilot can then look at the map or attend elsewhere as the virtual helicopter flies itself. There are absolutely no aerodynamics applied to the flight model. This is not what we are training.

The display is divided into three VGA resolution screens, one for each monitor. However, there is a 7° gap between each of the monitors for the plastic casing. We account for this by leaving a 7° gap in the graphics rendering. Consequently, as a pixel leaves one monitor, it does not instantly jump the gap to the next. These gaps are analogous to the aircraft's vertical windscreen support frames. Figure 2 shows a typical three screen view with gaps between screens.

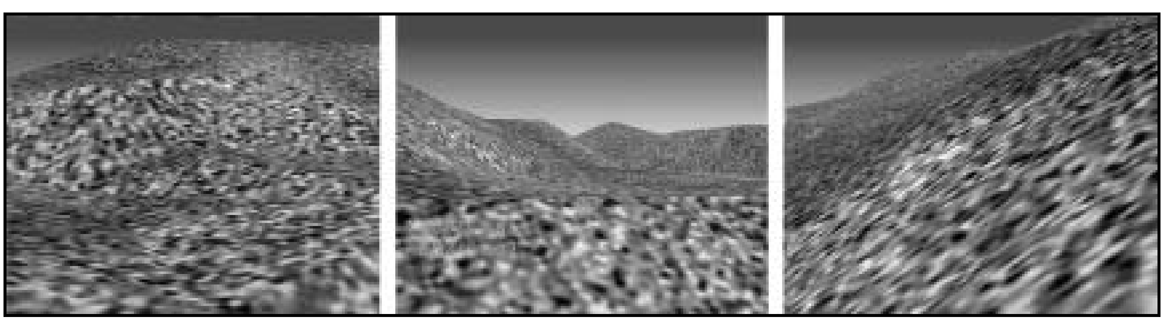


Figure 2. A typical three screen view with gaps between monitors.

Interface

The interface was designed to be easy to learn and consistent with the task of moving a viewpoint through the terrain as practice for contour map interpretation and visualization. However, there is one basic problem: Flying is generally a two-handed task. Map reading and interpretation is at a minimum a one-handed task under the best of conditions. In the aircraft, a pilot would never attempt both tasks simultaneously. For training, our contention is that interactive control is important [2]. We did not want pilots to feel like passive passengers but rather active participants. Therefore the interface needed to support completing both tasks simultaneously. It was important to design an interface that could be operated as easily by a single pilot as by a pair of pilots.

Although we had a wealth of specific domain knowledge actively involved in this project, we decided to bring the problem and our ideas to HS-10 and the helicopter pilot community at large to find out if we were on the mark. When helicopter pilots were presented with stick and throttle type controls, they were nearly split on which device should control each axis of movement. The transformation of stick and throttle to cyclic and collective is ambiguous. A narrow majority believed the throttle should act as a collective. When the stick is pulled back toward the user, the model should respond as a helicopter would if the collective were raised. A slight minority believed the throttle should act as a fixed wing throttle, i.e. it should control forward speed. Clearly, the results of our flight control usability study suggested our goal of building a system that was easy to use for everyone was not entirely achievable. After looking at our target user group, we still did not have a definitive answer to the question of control mechanism. We decided to look not only at the user group at large but also at the user group executing the training task at HS-10. This study brought out an issue we had not considered. If students rely on dead reckoning (DR) techniques, maintaining a constant ground speed should require little or no cognitive workload. However, if the speed is set by the cyclic, maintaining a constant ground speed requires excessive cognitive workload. The final compromise was to adopt a fixed wing mode where cyclic controls climb and yaw while throttle controls speed. There are no flight dynamic characteristics associated with the helicopter model motion. However, it was decided that extraordinary motion seemed like a good way to compensate for inherent limitations of training media. Since we can’t provide the same horizontal and vertical field of view of the real aircraft and are restricted with limited model fidelity, we can attempt to make up for such shortcomings by allowing users to do things only possible in a virtual world -- specifically flying backwards and the ability to detach the viewpoint from the helicopter.

The Exocentric View

While navigating, we typically only have an egocentric view available to us. This is our individual view from where we currently are looking through our own eyes. Previous research suggests that an exocentric view is a useful mechanism for acquiring information about a large-scale space [3, 4]. An exocentric view is one where the view is detached from the position of the egocentric view but is not necessarily perspective-less (infinitely far away and directly above) as would be the case in a conventional map. This view can be useful for navigation because it shows the local context around the viewpoint without losing perspective.

We originally considered using a "wingman" camera position tethered to the virtual helicopter. This was discarded because it fundamentally changed the navigation task. It is important that movement take place in the egocentric view only. The exocentric view was meant to provide help when needed but we feared it would become a crutch which, when taken away for the actual flight, would actually serve to lower performance rather than raise it. We also considered a separate window for the wingman view but also discarded it for similar reasons. If an exocentric view was to be used, it was essential that the transformation from it to the egocentric view be completely obvious.

We finally decided to integrate the exocentric and egocentric views. To minimize problems of disorientation associated with teleportation (e.g. a discontinuous transition), we decided on a fluid transition from the egocentric to the exocentric perspective. It is necessary that the user remain oriented throughout a training session. We developed a metaphor whereby the user detaches the camera from the model and controls the viewpoint with the flight stick. Holding the cyclic trigger switch while pulling back on the stick detaches the camera from the helicopter and moves it up a shallow 10° slope away from the helicopter. The viewpoint's speed of movement away from the helicopter is proportional to the stick displacement and distance squared from the helicopter. The viewpoint can be rotated about the helicopter by pushing the flight stick either left or right. When the trigger switch is released, the viewpoint reverses the path the user controlled and returns to the egocentric view. The animated motion is fluid and continuous. Figures 3 and 4 show exocentric views at two points along the glide slope. In Figure 3, the viewpoint has just been detached. The virtual helicopter model has been highlighted in this image. In Figure 4, the user has pulled further away such that the helicopter model has been replaced by its symbol. This has also been highlighted.

Figure 3. An exocentric view shortly after the view was detached.

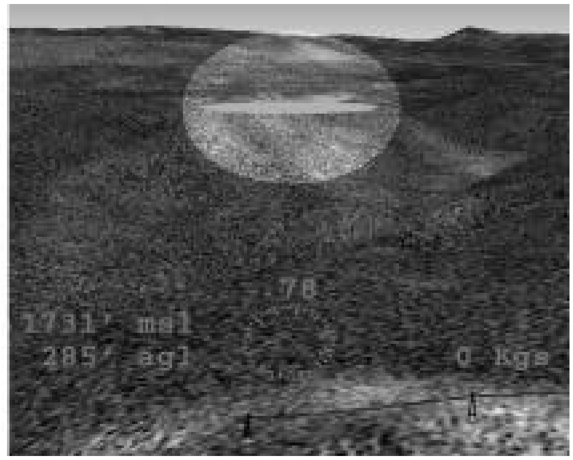


Figure 4. An exocentric view after the user has backed away from the helicopter position.

<u>The Heads-Up-Display</u>

The Heads-Up-Display (HUD) used is extremely simple. Again, we did not make any attempt to replicate the actual cockpit displays. We determined the essential flight parameters of interest to the terrain navigator and provided only that information: Mean Sea Level (MSL) altitude in feet, Above Ground Level (AGL) altitude in feet, true heading in degrees, and ground speed in knots. Figure 5 shows an enlarged image of the HUD from Figure 4. The display is red over mostly brown and green terrain and is therefore easier to read than might be suggested here in grayscale. In this example, the heading is 78°, the ground speed is 0 knots, and the altitude is 1731’ above sea level or 285’ above the ground at this point.

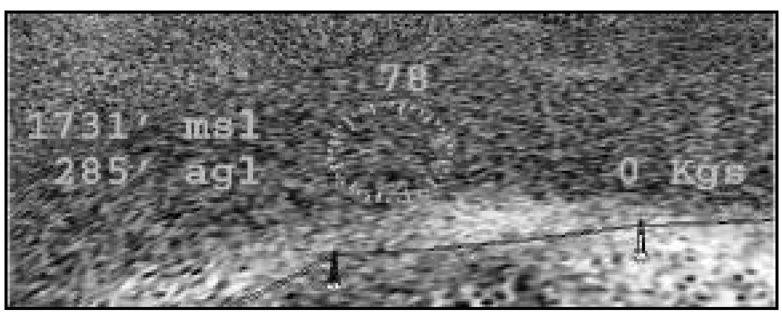


Figure 5. The Heads-Up-Display.

<u>The You-Are-Here Map</u>

It is essential that the student pilot not be lost for any extended duration during a training session. If the pilot becomes disoriented, pressing the spacebar calls up a You are Here (YAH) map. This map is a digital replica of the paper map they are using. The YAH map window can be moved, resized, and iconified. The spacebar toggles the YAH map on and off. When the YAH map is displayed, helicopter motion is frozen. If the student could view the map and move concurrently, the map would become a crutch. We observed pilots in earlier evaluations flying exclusively off of the map, not attending to the primary displays at all. By halting motion while the map is displayed, we have eliminated this counterproductive strategy. In principle, the map acts like standard moving map display. The helicopter remains centered with the map oriented in the helicopter’s direction of travel (track-up). This is consistent with previous work showing that track-up maps are most appropriate for egocentric tasks such as active navigation [5, 6]. This is reinforced by instructors at HS-10 who direct students to always turn their maps in the direction of travel.

The symbology on the map includes the intended track for various training routes (only one at a time), the own ship path showing where the virtual helicopter has been, and an icon representing the current position and orientation. The user can control the zoom factor on the map with a lever on the Flybox™. Pushing the lever forward, away from the user, zooms in while pulling back on the lever zooms out. Other map-related functions available to the user include going back to the last point at which they checked the map, erasing their track, selecting a different training route, and returning to the starting point. Figure 6 shows the YAH map with track data and helicopter symbol. The intended track is black while the actual track and helicopter symbol are red.

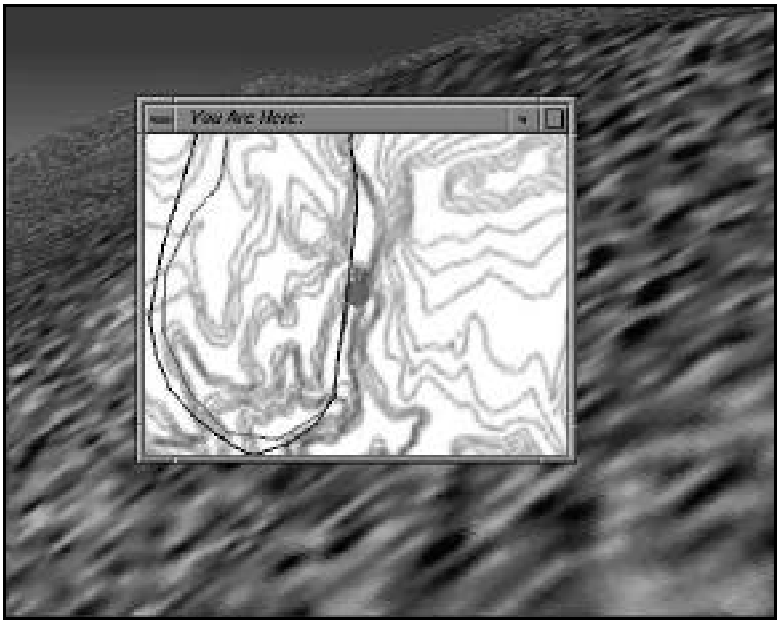


Figure 6. The You-Are-Here map.

The Terrain Database

The area we chose to model for the prototype system is the same terrain that student pilots will actually fly over -- specifically Marine Corps Air Station (MCAS) Camp Pendleton, California. However, we chose routes through this environment that differ significantly from those used by flight instructors. The modeled area is an 18 by 21 nautical mile (NM) region bounded by N33.25 W117.60 and N33.35 W117.25. We first obtained the Digital Elevation Terrain Data (DTED) for this area from the National Imagery and Mapping Agency (NIMA). We used DTED level one which is 100 meter resolution, unclassified, and publicly available. This was imported into the EasyTerrain™ terrain modeling tool by Coryphaeus, Inc. to produce a polygonal model. We then obtained geo-rectified multi-spectral satellite imagery from the Naval Space Command which we used for texture over the polygonal model. The resolution of the satellite imagery is 30 meters and is also unclassified and publicly available. The imagery texture works well for distant views or high fly-over applications such as those typical of TOPSCENE. However, from low altitudes, the local area appears very pixelated with large colored blocks where texture pixels are spread over a large region. This lack of realism did not disturb us until it was determined that it had a strong negative effect on navigation performance. It became difficult to determine relative ground speed via optical flow. This makes dead reckoning techniques difficult if not impossible. To remedy this, we added a detailed texture which, when viewed up close, overlays the imagery texture. The detail texture was created using the random noise generation features of Adobe Photoshop™. Colors were selected to match the general appearance of Camp Pendleton foliage -- dry grass and low chaparral. This texture management technique is intended to preserve the quality of information available from satellite imagery for distant terrain while improving the appearance of terrain close to the viewer. We do not believe that detailed texture completely eliminates problems associated with ground speed estimation. However, it was made clear through our usability tests that the task was not always possible without the use of detailed texture.

We did not include vegetation in the model. Our intent was to focus on terrain navigation. Vegetation can be used as a landmark. After a landmark can be recognized, there is no longer a reason to resolve the contour map to cockpit views. In other words, map reading stops and the navigation skills necessary to be a successful pilot do not develop further. If we add vegetation in the future, it will be to add velocity, height, and depth of field cues. We will not try to replicate the real world. We believe that randomly placed vegetation of uniform size and appearance may be a great benefit in helping pilots use dead reckoning techniques which are an essential part of resolving terrain to contour maps.

For similar reasons, very few man-made features are modeled. While military pilots are trained not to use cultural features such as roads and power lines for navigation, they do. It is not our intent to reinforce bad habits. However, during our usability tests, we discovered that in practice, power lines are far too important a hazard to not be modeled. Therefore we made exceptions to add primary roads and power lines to the model.

EXPERIMENT

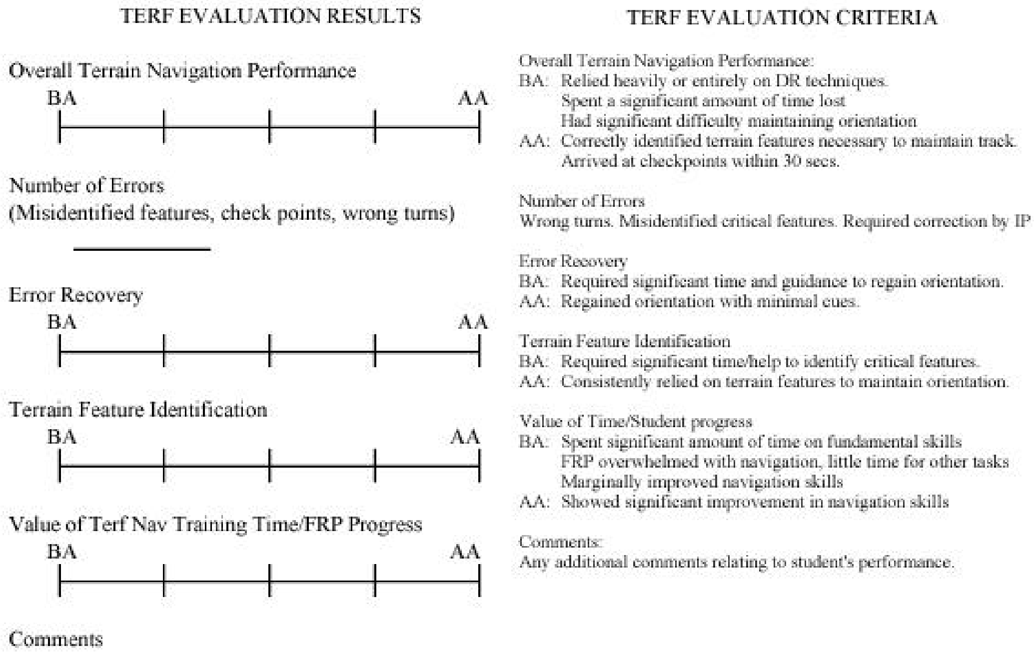
To determine if our prototype implementation was actually improving navigation performance, we designed an experiment with the cooperation of HS-10 to evaluate student pilots' navigation abilities. Although there are probably other ways of determining if transfer of training is occurring, we decided that the only reasonable measure was to use conventional evaluation techniques already in place. However, the curriculum at HS-10 is extremely full so we had to fit our experiment into their schedule as time would allow. The positive side of this is that we did not disturb the training process, so if an improvement is detected, we can be confident that it was due to differences we introduced (e.g. the VE trainer). The negative side of this is that we had less control than we would have liked. In particular, we were not allowed in the aircraft during the training flight. Consequently, there may be variability in instructor evaluation we cannot attribute to student performance.

There were two experimental groups of twelve students each; the control group which received only conventional map study and ground school preparation, and the virtual environment group which received the same preparation as the control group in addition to one hour on the virtual environment trainer. As of the writing of this paper, six CAT-1 pilots have completed training in the virtual environment group. CAT-1 pilots are recent flight school graduates who are not switching platforms but are entering their first graduate level instruction specializing in one helicopter – in this case, the H-60 Seahawk. Our students are all males, ages 22 to 25, with ranks of LTJG (O-2) to LT (O-3).

After an introductory brief of the procedure and instructions, participants in the virtual environment group were given a quick test to ensure that they understood and were able to use the system properly and that they were familiar with the available features. Only one planned route was given in this experiment. This route is depicted on both the virtual and paper maps. They were instructed to try to fly the route as closely as possible. We measured the number of times the virtual map was accessed and the location of the virtual helicopter. A "perfect" run is one in which the student flies the route without mistakes and does not need to access the virtual map or exocentric view at any time – all navigation is done off of the paper map alone. This is the best case since this is what will occur later in the aircraft. However, students are not discouraged from accessing the virtual map. A "think aloud" verbal protocol was used to gather qualitative information about confidence and strategies used by the student. This is far more indicative of navigation abilities than quantitative measures because a disoriented or confused student cannot describe upcoming terrain features with any accuracy. It is possible, however, to guess correctly as to which way to go.

The control group receives only conventional map preparation. They are given 1:50,000 topological maps of the Camp Pendleton area. They are told the route they will fly. There are a number of checkpoints they must pass along the way. Their task is to familiarize themselves with the area via the map such that they will be able to navigate in the aircraft. Conventional preparation does not include any three-dimensional tools whatsoever.

All participating pilots are evaluated in an identical fashion. When in the aircraft, they are the navigating pilot. It is their task to direct the flight instructor who is the flying pilot. The flight instructor will usually ask questions about features they see to determine if the student is cognizant of the surrounding area. Students are asked to describe upcoming features and cues used to direct flight. Following the flight, the flight instructor will evaluate the student as usual on a typical grade card. These cards ask specific questions about performance on the flight – in this case on navigation ability. In addition, we added a number of questions on a grade card addendum that are specific to this experiment (See Figure 7).



TERF EVALUATION RESULTS

Overall Terrain Navigation Performance

BA AA

Number of Errors
(Misidentified features, check points, wrong turns)

Error Recovery

BA AA

Terrain Feature Identification

BA AA

Value of Terf Nav Training Time/FRP Progress

BA AA

Comments

TERF EVALUATION CRITERIA

Overall Terrain Navigation Performance:
BA: Relied heavily or entirely on DR techniques.
Spent a significant amount of time lost
Had significant difficulty maintaining orientation
AA: Correctly identified terrain features necessary to maintain track.
Arrived at checkpoints within 30 secs.

Number of Errors
Wrong turns. Misidentified critical features. Required correction by IP

Error Recovery
BA: Required significant time and guidance to regain orientation.
AA: Regained orientation with minimal cues.

Terrain Feature Identification
BA: Required significant time/help to identify critical features.
AA: Consistently relied on terrain features to maintain orientation.

Value of Time/Student progress
BA: Spent significant amount of time on fundamental skills
FRP overwhelmed with navigation, little time for other tasks
Marginally improved navigation skills
AA: Showed significant improvement in navigation skills

Comments:
Any additional comments relating to student's performance.

Figure 7. The grade card addendum used for the experiment.

RESULTS

Without a control group to compare to, it is premature to draw strong conclusions about student performance in the aircraft. However, based on students' interaction with the training system, we can draw several significant conclusions.

It is feasible to use an unaltered pre-existing task (training CSAR skills to helicopter pilots) as the measure of effectiveness of a proposed training aid. At the outset, it was uncertain if it would be possible to implement and measure the effectiveness of a terrain navigation training aid without altering the existing training syllabus. While coordinating the implementation around a fixed training course presents many unique logistic challenges, it eliminates all questions related to training transfer. If navigation performance in the aircraft improves for those students who use the navigation trainer, there can be no question concerning its effectiveness. Although there is considerably more overhead associated with data collection and less empirical data to study, improved student performance in the aircraft is the ultimate goal of a training system, and was precisely what we measured. We believe this is the ideal situation since it raises few questions regarding effectiveness and definitively answers the one question we needed an answer to. A downside to this method is that it does not lend itself easily to discovering unanticipated effects that might lead to even better training systems in the future. We need to rely on flight instructors as the final judge and jury of the system. We were not present in the aircraft ourselves.

The task of navigating through a model of Camp Pendleton is an achievable goal. This was not a foregone conclusion prior to evaluating students at HS-10. Although several helicopter pilots familiar with the Camp Pendleton area felt comfortable navigating through the virtual model, they relied primarily on memory rather than the feedback provided by the system. While it was encouraging that pilots were able to accurately identify their location based exclusively on the forward field of view provided in the simulation, this did not tell us what would happen when people without prior exposure to the Camp Pendleton area were tasked with navigating through the model. One of the key areas of uncertainty is whether the digitally recreated contour map correlated closely enough with the scene. All six students tested were able to complete the depicted route within the allotted time. Additionally, after initially completing the route, four of the six students were able to either complete the route in the reverse direction or repeat the route in the same direction a second time. Furthermore, it was clear from verbal data that they were working to resolve the map to what they saw on screen. They were not simply trying to get familiar with the region in question. Students commented on the shape of the ground around them in great detail. They stated well ahead of time what they expected to see and where it would appear. When they made errors or drifted off course, they were able to quickly recover by resolving what they saw on screen to the map rather than vice versa. This is taught in flight school as working “outside-in” rather than “inside-out”. The navigator’s eyes should be outside as much as possible, not inside scanning the map.

This study also validated the fact that the interface and feedback are effective. Although the interface had been evaluated during usability studies, it was never evaluated with the precise target user group. The usability study used non-aviators (including USMC Infantry, USN Surface Warfare and Supply Corps Officers), fixed wing aviators and helicopter pilots. Although it may be assumed that the helicopter pilots would provide the closest approximation to the target user group, there were significant differences between the pilots tested and the ultimate user group. The minimum flight time of the helicopter pilots tested was approximately 1500 hours. All had extensive fleet experience with overland terrain navigation. One of these subjects successfully completed initial test routes without reference to feedback mechanisms. The non-aviators more closely approximated the level of terrain navigation experience of the target user group. However, the target user group would have an average of 90 fixed wing and 120 helicopter hours. Additionallly, fixed wing training involves approximately 43 hours in various simulators. Helicopter training involves approximately 34 hours in the simulator. We were uncertain if this would impact their expectations and thus adaptation time (learning curve) to the interface.

All of the students tested at HS-10 adapted quickly to the interface and were able to control motion and access feedback mechanisms easily. As predicted by the usability studies, two of the students initially expected the throttle lever to act as a collective. These students did not appear to have any more difficulty interacting with the system than the other students after the first few minutes of exposure. Based on observations of students interacting with the system, we conclude that the interface was in fact consistent with the task of learning to interpret contour maps. It allowed students to experience the terrain model with adequate attention to resolving the egocentric view to the contour map.

The training system appears to do what it was designed for -- provide students the opportunity to improve their ability to resolve an egocentric view with a contour map representation. Based on observations and verbal protocol, it was apparent that all of the students showed at least incremental improvement in this skill. This will require final validation after their training flights but we are optimistic that we will see at least moderate gains in performance by the estimation of their flight instructors. Additionally, students showed a wide variance in both initial skill level and progress made during the training sessions. The variance in both initial skill level and progress supports the concept of asynchronous access and easy availability. Clearly, if performance during the training sessions can be shown to correlate to performance in the aircraft, the training system should be readily available to all pilots. If initial skill level and rate of progress vary, students should be able to access the system as many times as they need to for how ever long than feel they need it.

CONCLUSIONS

This experiment is incomplete as of the writing of this paper. Nevertheless, we feel confident that the ability to practice this skill in a system such as this one will prove valuable to HS-10. Our future plans include an actual field test of a system to allow instructors there the opportunity to see if it has a place in the curriculum. This will also allow us the opportunity to study long term evaluation periods that were not possible in this first experiment. The steps left to complete this goal include porting the system to the Windows NT platform and a further analysis of exactly what effect this trainer has on navigation ability.

Before the Navy can take any steps toward training navigation on the ground in lieu of in the air, this effect must be a known quantity. However, navigation is a part of every task in the air, so this trainer would never completely replace experience in the aircraft. The primary benefit would be that navigation would not *explicitly* be trained in the air.

Most people who have seen the system point out its potential as a mission rehearsal system. We agree that the potential exists. However, there is a hidden danger in this thinking. It is easy to fall into the trap of training only routes when mission rehearsal system are used. In these cases, the pilot knows how to get to the target one and only one way. If problems occur during the mission forcing a change in route, the pilot is actually worse off than if no rehearsal had taken place. There are ways around this pitfall that we are attempting to identify for the helicopter community. Again, solutions from the fixed wing community may not apply since flight profiles for helicopter missions are so completely different. Nevertheless, our intention is to continue to learn more about the uniqueness of rotary wing aircraft and how this burgeoning technology can be brought to bear on their training and operational problems.

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